Economic Epidemiology of Malaria and Economic Growth

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Plan of the presentation

A. Basic Facts about Malaria
   - Global incidence, and significance

B. Biology of Malaria Parasites
   - Life cycle (requires both human and vector as hosts to complete its life cycle)
   - Symptoms and Health Consequences
   - Treatment
   - Drug resistance
   - Vaccines

C. Economics of Malaria Disease (main purpose of this paper) (next slide)

Plan of the presentation continued

Main purpose:

- I model the disease dynamics and its effects on income growth using human capital approach to demand for health, I.e., based on economic calculations.
- Predictions of this economic model differ from the purely epidemiological model in terms of the short-run and long-run behavior of the disease, its effect on economic growth, welfare losses, timing of drug-resistance, and implications for public policies - for example, the extent to which public control programs could be privatized through tax-subsidy policies or community level incentives, educating population about the real effects of malaria
- The model generates Malthusian poverty trap all over again.

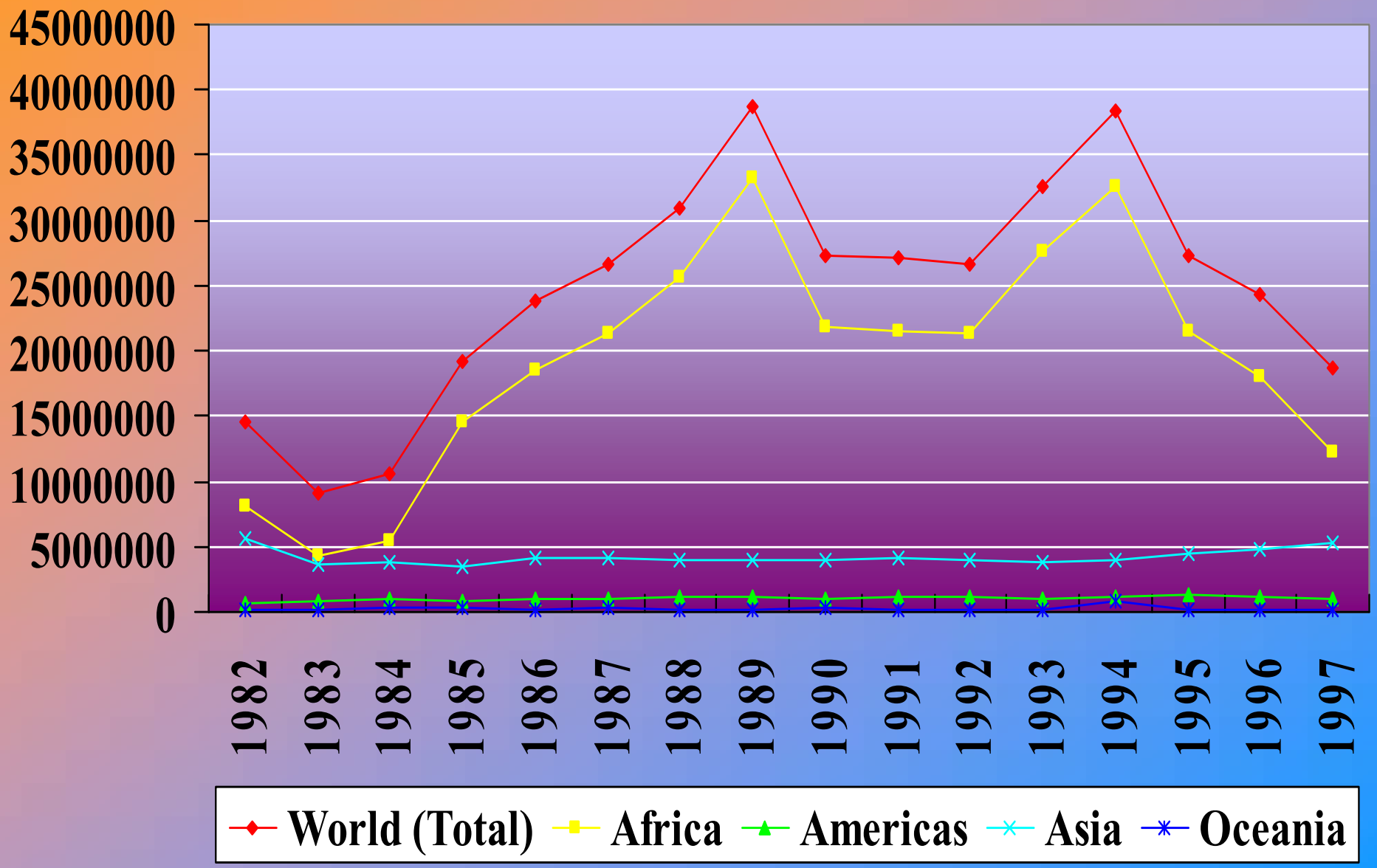
Basic facts about Malaria

- Malaria is a public health problem today in more than 90 countries, inhabited by a total of some 2 400 million people -- 40% of the world's population.
- Worldwide prevalence of the disease is estimated to be in the order of 300-500 million clinical cases each year.
- More than 90% of all malaria cases are in sub-Saharan Africa.
- Mortality due to malaria is estimated to be over 1 million deaths each year. The vast majority of deaths occur among young children in Africa, especially in remote rural areas with poor access to health services.
- Malaria kills one child every 30 seconds. In absolute numbers, malaria kills 3 000 children per day under five years of age.

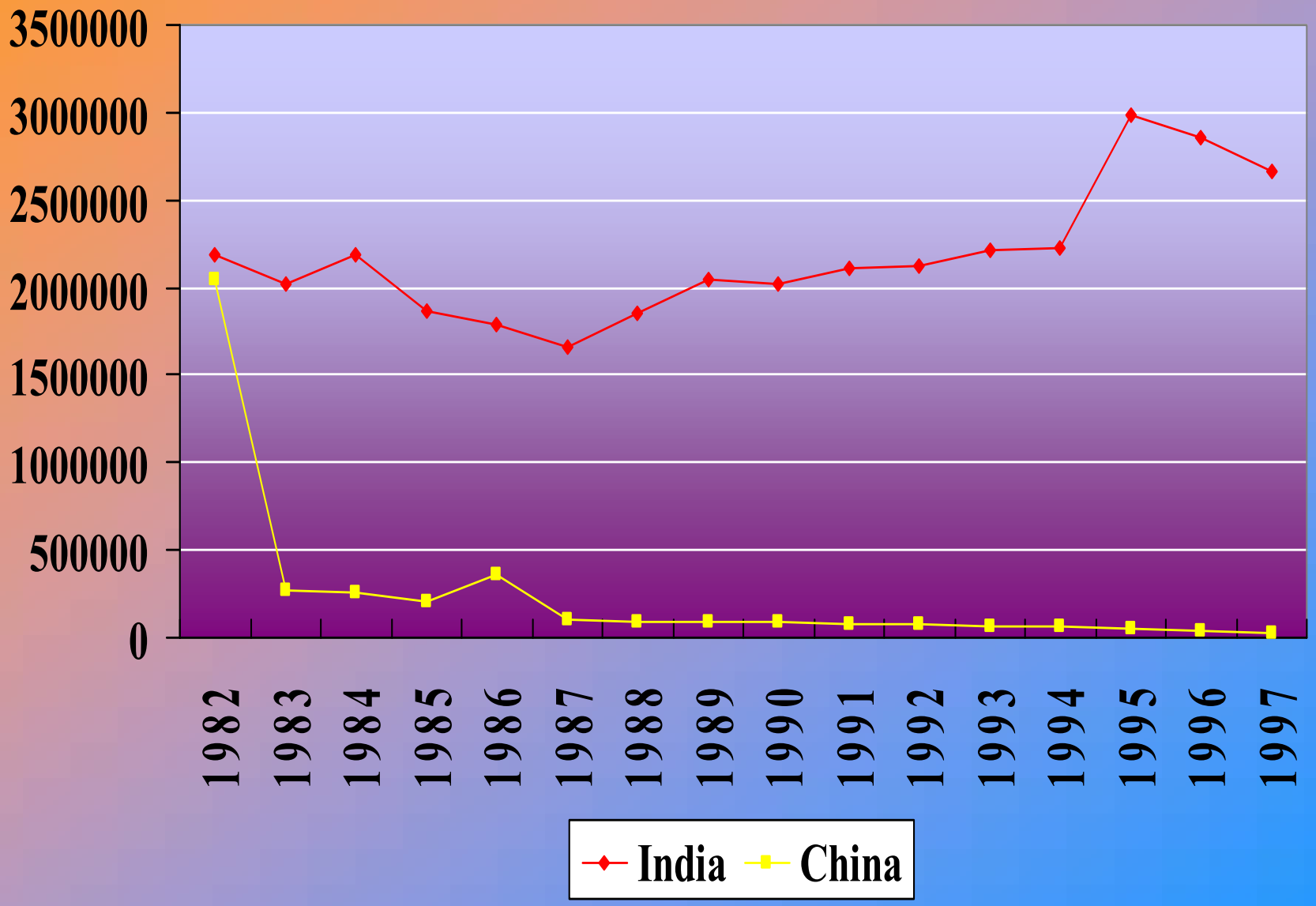
Basic Facts (continued)

- Other high-risk groups are women during pregnancy, and non-immune travelers, refugees, displaced persons and laborers entering endemic areas.
- Malaria epidemics are caused by political upheavals, Global warming" and other climatic events such as "El Niño“, International travels and migration and labor mobility, irrigation projects.
- Malaria is endemic in a total of 101 countries and territories: 45 countries in WHO's African Region, 21 in WHO's Americas Region, 4 in WHO's European region, 14 in WHO's Eastern Mediterranean Region, 8 in WHO's South-East Asia Region, and 9 in WHO's Western Pacific Region.

World incidence of Malaria over time



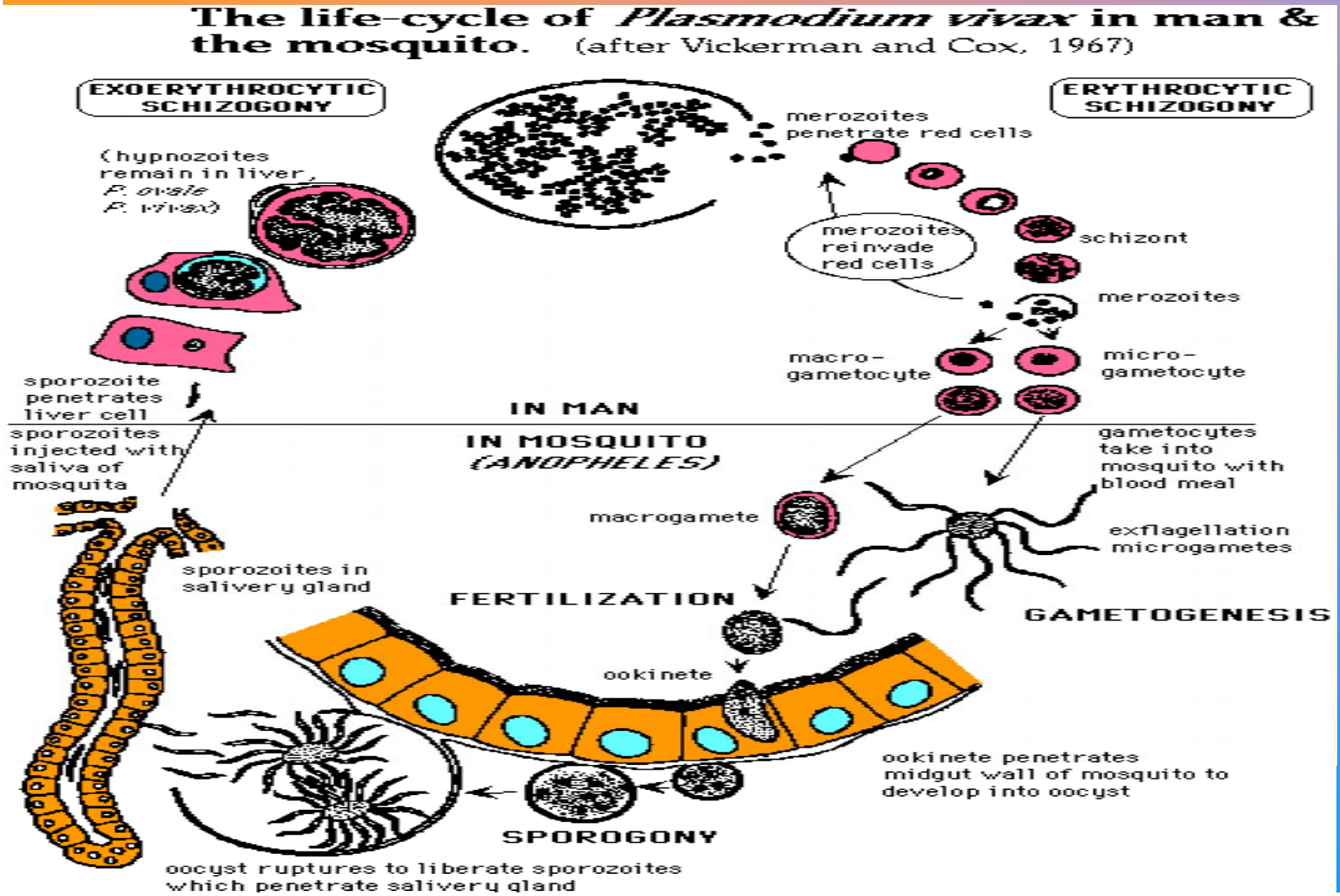
China and India



Malarial species (Four Serious ones)

- P. falciparum (the grim reaper)
  - Lethal disease.
  - Wide distribution (Especially Sub Saharan Africa & Melanesia)
- P. vivax
  - Chronic, more benign infection
  - Americas, N Africa, Middle East, India
- P. ovale (W Africa)
- P. malariae (Africa and elsewhere)

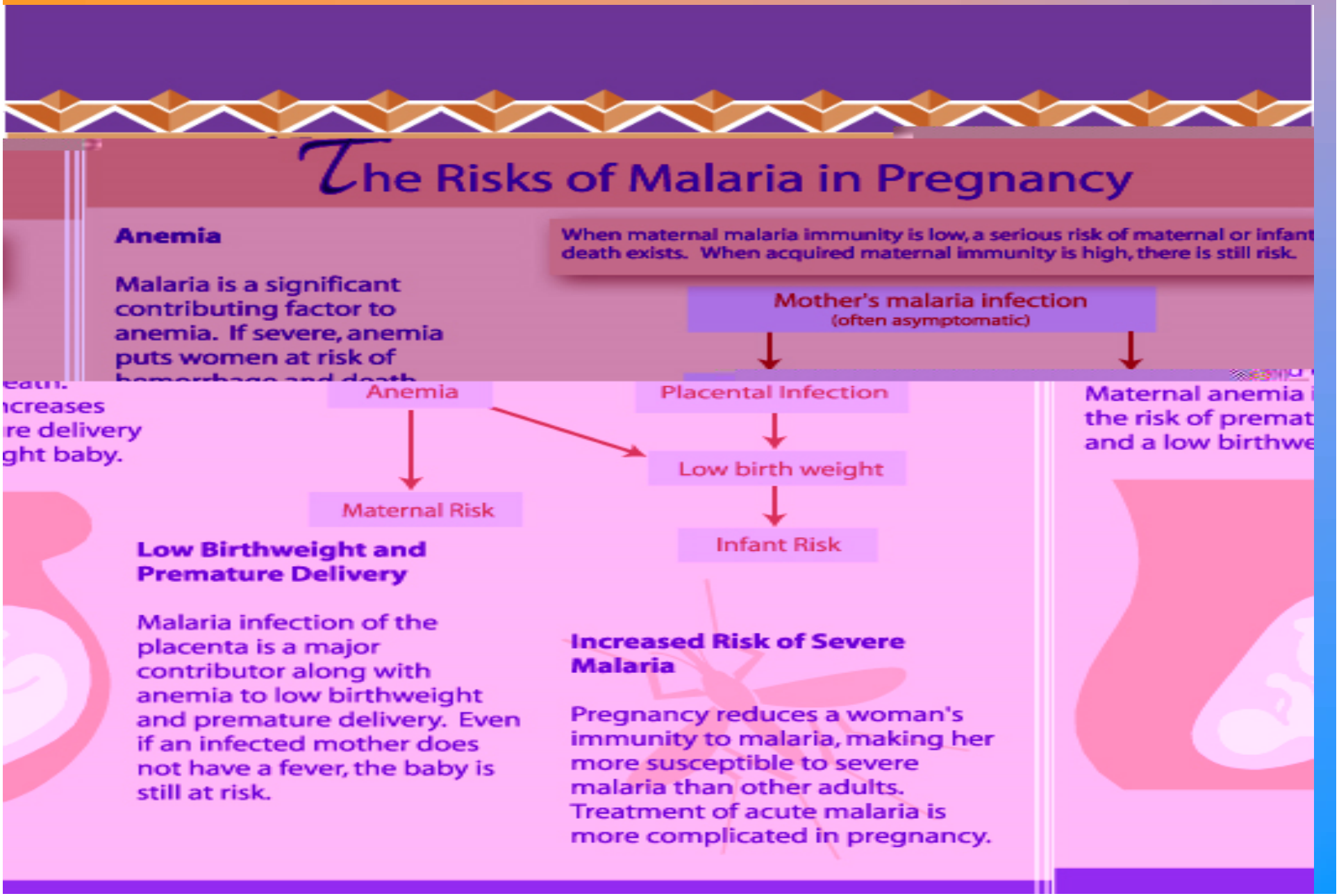
Parasite's life-cycle (in man and female mosquito)



Symptoms and Health Consequences

- As the shizonts mature in the liver, huamn host gets high fever (maybe above 41^{o}C), shivering, pain in the joints, headache, repeated vomiting, convulsions and coma.
- P. falciparum (acute sequestration)
  - Cerebral malaria (fits, coma, death)
  - Hypoglycaemia (kids), lactic acidosis
  - Severe anaemia (haemolysis)
  - Renal failure, multi-organ failure
- P. vivax, P. malaria, P. falciparum (chronic disease)
  - Tropical splenomegaly, splenic rupture, Immune
  - complex glomerulonephritis
- During Pregnancy (next slide)

Lives at risk (pregnant women)



Treatment: Preventive care

1. insecticide impregnated mosquito nets (most cost effective)
2. prophylactic drugs (expensive and meant for occasional use)
3. Some substance from coconut tree, throwing those in ponds can kill mosquito larva (yet at development stage)
4. Replacing world mosquito population with genetically engineered mosquito having high resistance towards reproductive cycle stage of P. falciparum in mosquito (still at research stage).
5. Vaccines (one at clinical trial, and other ones under development). For details, see the vaccine slide.

Treatment: Curative care

Antimalarial drugs:

1. chloroquine oldest medicine but widespread drug-resistance
2. Sulfadoxine/pyrimethamine
3. Artemisnins, right now the drug of the last resort and P.falciparum, has not yet developed drug resistance

Vaccines Development

- Vaccines are at clinical testing stage. Different vaccines target different stages of life cycle of P.falciparum
- Pre-erythrocytic vaccines
  - Prevent sporozoite from entering or developing within liver cells (currently one vaccine is under field trial in the Gambia).
- Asexual blood stage vaccines
  - Prevent the merozoite from entering or developing within red blood cells.
  - Would not prevent people from getting infected, but would provide immunity for the symptom causing blood stage.
- Transmission-blocking vaccines
  - Inhibit development of sexual stages of parasite (currently undergoing clinical trials)

Economics of Malaria- household demand Preventive and curative care

Human Capital approach to investment in health:

- Agent, α : vary according to age, a, schooling level s, stock of health capital h^a and thus parental income level.
- Malaria season is at the beginning of each period. The likelihood of malaria infection if one does not use the malaria prevention package depends on the malaria prevalence rate i_t at the beginning of the period. Uncertainty about malaria infection is resolved at the beginning of a period.
- In each period t given his health stock, financial assets, and the malaria infection rate i_t at the beginning of the period, an individual decides whether to invest in malaria preventive care package, after the malaria period is over, he goes to work and decide how much to save.
- If he is infected with malaria, he has to spend x^c curative care, he loses $0 < T < 1$ hours of work, and $0 < H < 1$ fraction of his health capital.
- Then decisions are guided by expected utility maximization.

General Model:

$$h^a = h^{a-1}\left(1-\delta\left(\eta_t\right)\right),\ h^0 = \tilde{h} \tag{3}$$

$$V_t^{a,s}\left(k_t,h_t\right) = \max_{\theta_t,k_{t+1},c_t} E_{\eta_t} u\left(c_t\right) + \beta \cdot V_{t+1}^{a+1,s}\left(k_{t+1},h_{t+1}\right) \tag{4}$$

$$c_t + \theta_t x_t^p + k_{t+1} + \left(\eta_t|\theta_t\right)x_t^c = \left(1+r_t\right)k_t + w_t b_t e\left(a,s,h_t\left(1-\delta\left(\eta_{t|\theta_t}\right)\right)\right)\left(1-\left(\eta_t|\theta_t\right)T\right)$$

Denote by $\left(\theta_t^{a,s}\left(k_t,h_t\right), k_{t+1}^{a,s}\left(k_t,h_t,\theta_t,\eta_t|\theta_t\right)\right)$ the optimal policy function of the individual of age a in period t with initial health capital h_t and asset holding k_t. Denote by

$$\bar{s}_{t+1} = \left(1-\bar{\theta}_t\right)\cdot\left(1-p\left(\bar{s}_t\right)\right) \tag{2}$$

$$K_{t+1} = N_t \sum_{a,s,k_t,h_t,\eta_t|\theta_t^{a,s}(.)} k_{t+1}^{a,s}\left(k_t,h_t,\theta_t^{a,s}\left(.\right),\eta_t|\theta_t^{a,s}\left(.\right)\right)\cdot p\left(\eta_t|\theta_t^{a,s}\left(.\right)\right)\cdot \pi_t^{a,s}\left(k_t,h_t\right) \tag{9}$$

$$L_t = N_t b_t \varphi_t \tag{10}$$

$$b_{t+1} = \left(1+\gamma_t\right)b_t,\ b_0 = 1. \tag{11}$$

$$\gamma_t \equiv \hat{\gamma}\left[R_t\right]^{\mu}, 0 \le \mu \le 1, \hat{\gamma} > 0 \tag{12}$$

Definition 2 A *malaria afflicted competitive steady-state equilibrium* is a malaria infection rate i^*, capital-labor ratio in efficiency unit $\tilde{k}^*$, growth rate of per capita income, γ^*, a collection of value functions value funcitons $V^{a,s}(k,h)$, optimal malaria preventive care decisions $\theta^{a,s}(k,h)$, optimal asset holding decisions $k^{a,s}(k,h,\theta^{a,s}(),\eta|\theta^{a,s}())$, and a distribution of population $\pi^{a,s}(k,h)$, and a transition probability distribution $\Gamma^{a,s}(k',h'|k,h)$ such that

1. $i^* = \left(1-\bar{\theta}\left(i^*\right)\right)\left(1-p\left(i^*\right)\right)$.
2. Probability of malaria given the choice of malaria preventive care, $\eta|\theta$ is given by

$$p(\eta=1|\theta) = \begin{cases} 0 & \text{if } \theta = 1 \\ 1-p\left(i^*\right) & \text{if } \theta = 0 \end{cases}$$

3. $w_t = b_t\hat{w}$, where $\hat{w} = f\left(\tilde{k}^*\right) - f'\left(\tilde{k}^*\right)\cdot\tilde{k}^*$ and $r_t = f'\left(\tilde{k}^*\right)$
4. Given i^*, r, w, the value functions $V^{a,s}(k,h)$, the policy functions for preventive care decision $\theta^{a,s}(k,h)$ and investment in financial assets $k^{a,s}(k,h,\theta,\eta|\theta)$ solve equations (4)-(5).
5. The transition probability distributions satisfy

$$\Gamma^{a,s}(k',h'|k,h) = \sum_{k,h}\mathcal{I}\left(k'-k^{a,s}(k,h,\theta,\eta|\theta),h'-h\left[1-\delta\left(\eta|\theta^{a,s}()\right)\right]\right)\cdot p\left(\eta|\theta^{a,s}()\right)$$

6. Invariant distributions of population satisfy

$$\pi^{a,s}(k,h) = \frac{1}{1+n}\sum_{k^-,h^-}\Gamma^{a-1,s}(k,h|k^-,h^-)\cdot\pi^{a-1,s}(k^-,h^-)$$

and for the first age group,

$$\pi^{1,s}(k,h) = \begin{cases} \frac{1}{1+\xi} & \text{if } k=0, h=\hat{h} \\ 0 & \text{otherwise} \end{cases}$$

7. The capital-labor ratio in efficiency unit

$$\tilde{k}^* = \frac{\sum_{a,s,k,h,\eta|\theta^{a,s}(.)} k^{a,s}(k,h,\theta^{a,s}(.),\eta|\theta^{a,s}(.))\cdot p\left(\eta|\theta^{a,s}(.)\right)\cdot\pi^{a,s}(k,h)}{\sum_{a,s,k,h,\eta|\theta^{a,s}(.)} e(a,s,h)\left[1-\left(1-\theta^{a,s}(.)\right)\left(\eta|\theta^{a,s}(.)\right)\cdot\mathcal{I}\right]\cdot p\left(\eta|\theta^{a,s}(.)\right)\cdot\pi^{a,s}(k,h)}$$

8. $\gamma^* = \hat{\gamma}\left[\sum_{a,s,k,h,\eta|\theta^{a,s}(.)}\gamma(a,s,h)\left[1-\left(1-\theta^{a,s}(.)\right)\left(\eta|\theta^{a,s}(.)\right)\cdot\mathcal{I}\right]\cdot p\left(\eta|\theta^{a,s}(.)\right)\cdot\pi^{a,s}(k,h)\right]^{\mu}$

Malaria free equilibrium
Incomplete information
ρ'(i)
ρ(i)
Full information
malaria endemic equilibria
0
i'^C
i^C
- i -
i*
i'*
1

The End

Thank you for your comments and for coming